TP 4978E

# Report on Arctic Ship Navigation Tasks

prepared for

Transportation Development Centre
Transport Canada
Montreal, Quebec

Malcolm G. Lowings
Martec Limited
Calgary, Alberta

March 1984

Library and Information Centre/
Centre de Documentation (GSLA)
RECEIVED CU LE
AUG 27 1984
Transport Canada / Transports Canada

The contents of this report reflect the views and opinions of the contractor, and not necessarily the official views or policies of the Transportation Development Center.

## REPORT DOCUMENTATION FORM

| 1. Transport Canada Report No. | 2. TDC Project No. | 3. Recipient's Catalogue No. |
|---|---|---|
| TP 4978E | 6022 | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| Report on Arctic Ship Navigation Tasks | March 1984 |
| | 6. Performing Organization Report No. L021 |
| 7. Author(s) Malcolm G. Lowings | 8. Transport Canada File No. D1460-145-11 |
| 9. Performing Organization Name and Address<br>Marctec Limited<br>400 Monenco Place<br>801 - 6 Avenue S.W.<br>Calgary, Alberta T2P 3W3 | 10. DSS File No.<br>11. DSS or Transport Canada Contract No. |
| 12. Sponsoring Agency Name and Address<br>Transportation Development Centre<br>1000 Sherbrooke Street West<br>Suite 2421<br>Montreal, Quebec H3A 2R3 | 13. Type of Report and Period Covered<br>Final: June 1983 - March 1984<br>14. Sponsoring Agency Code<br>TDC 6022 |
| 15. Supplementary Notes | 16. TDC Project Officer<br>Dr. Ruth M. Heron |

17. Abstract

Information on Arctic ship operations was collected during the voyage of an ice-capable vessel to/from the eastern Canadian Arctic in the fall of 1982. This material was used to study the decision-making process on the bridge, and the condition of the ship for navigating ice-infested waters. Seven representative incidents, or encounters, between the ship and various hazards to navigation were used to discuss some of the decisions made by personnel on the bridge, and some of the factors that contributed to these decisions. The ship's appointments for Arctic trade, command structure and watch-keeping system, emergency procedures, and ice experience of ship's personnel are also discussed.

The ship was well-found for Arctic trade, and was operated in a competent, professional manner during the voyage. Important factors for decisions made on the bridge include visual observations, experience, and familiarity with the ship and her performance in different ice conditions. At night or times of reduced visibility, radar observations were major influences. An electronic image intensifier (or night vision system) greatly aided detection of growlers at night, plus route selection and close maneuvers for transmitting zones of hazardous and non-hazardous ice. Ice reconnaissance data were used for strategic purposes, but generally not for actions or decisions related to the tactical situation ahead. Based on observations made during the passage, the ship was navigated in a conservative fashion. Proper detection of hazards, and the perception of acceptable risk, were major concerns in this regard.

| 18. Key Words | 19. Distribution Statement |
|---|---|
| Ships, Navigation, Arctic, Ice, Hazards, Decision-making, Visual Perception. | A limited number of copies of this report are available from Transportation Development Centre. |

| 20. Security Classification (of this report) | 21. Security Classification (of this page) | 22. No. of Pages | 23. Price |
|---|---|---|---|
| Unclassified | Unclassified | | Nil |

TDC/CDT 79-005

## FORMULE DE DOCUMENTATION POUR RAPPORT

| 1. Nº du rapport Transports Canada | 2. Nº de l'étude — CDT | 3. Nº de catalogue du destinataire |
|---|---|---|
| TP 4978E | 6022 | |

| 4. Titre et sous-titre | 5. Date du rapport |
|---|---|
| Report on Arctic Ship Navigation Tasks | mars 1984 |
| | 6. Nº du rapport de l'organisme exécutant<br>L021 |

| 7. Auteur(s) | 8. Nº de dossier Transports Canada |
|---|---|
| Malcolm G. Lowings | D1460-145-11 |

| 9. Nom et adresse de l'organisme exécutant | 10. Nº de dossier — ASC |
|---|---|
| Marctec Limited<br>400 Monenco Place<br>801 - 6 Avenue S.W.<br>Calgary, Alberta T2P 3W3 | 11. Nº de contrat — ASC ou Transports Canada |

| 12. Nom et adresse de l'organisme parrain | 13. Genre de rapport et période visée |
|---|---|
| Centre de développement des transports<br>1000 ouest rue Sherbrooke<br>Suite 2421<br>Montréal, Québec H3A 2R3 | Finale: juin 1983 - mars 1984 |
| | 14. Code de l'organisme parrain<br>TDC 6022 |

| 15. Remarques additionnelles | 16. Agent de projet — CDT |
|---|---|
| | Dr. Ruth M. Heron |

17. Résumé

L'information recueillie à bord du navire, qui au cours de l'automne de 1982 a navigué dans les eaux arctiques canadiennes dans les deux sens, a été dépouillée pour que puissent être étudiés le processus par lequel se prennent les décisions à bord et aussi l'aptitude du navire à naviguer dans des eaux chargées de glaces. Le rapport fait état de sept incidents ou rencontres de divers obstacles gênant la navigation, lesquels ont servi à analyser quelques-unes des décisions qui ont été prises sur le pont et à éclairer quelques-unes des décisions qui ont été prises sur le pont et à éclairer quelques-uns des facteurs contributifs. Il traite également de l'armement du navire lors des périples arctiques, de la chaîne de commandement et du système de veille, ainsi que des procédures d'urgence et de l'expérience de l'équipage en matière de navigation dans les glaces.

Le navire en question a été trouvé apte aux missions arctiques. Il était commandé et dirigé par un équipage hautement qualifié. Parmi les facteurs contributifs aux prises de décision, on peut mentionner les observations visuelles, l'expérience, la connaissance du navire et de son comportement en diverses circonstances. La nuit, ou par mauvais temps, les observations radar ont beaucoup influé sur les décisions. L'utilisation d'un amplificateur électronique des rayons lumineux (ou système de vision nocturne) a grandement aidé à la détection nocturne des bourguignons, à la sélection du chemin à suivre et aux manoeuvres précises dans les eaux chargées de glaces plus ou moins dangereuses à la navigation. Les données transmises par les patrouilles de reconnaissance des glaces ont été utiles sur le plan global, mais pas à l'égard des actions ou des décisions liées à la situation qui se présentait au fur et à mesure. D'après les observations faites, la navigation a été marquée au coin de la prudence, obéissant en cela à des impératifs tels que la détection en temps utile des obstacles et l'évaluation serrée de la situation.

| 18. Mots-clés | 19. Diffusion |
|---|---|
| Navires, Navigation, Arctique, Glaces, Obstacles, Décisions, Observations visuelles. | Le CDT dispose d'un nombre limité d'exemplaires. |

| 20. Classification de sécurité (de ce rapport) | 21. Classification de sécurité (de cette page) | 22. Nombre de pages | 23. Prix |
|---|---|---|---|
| Non-classifié | Non-classifié | | Aucun |

## Acknowledgements

The author wishes to acknowledge the counsel and assistance kindly provided by Dr. R.M. Heron, the Scientific Officer for this study. Her suggestions, guidance, and continuing interest are greatly appreciated.

The owners are thanked for permitting, and expediting, the author's participation in the voyage. The ship's master, officers and crew gave freely of their time and knowledge during the passage; the author's reception aboard was very warm and helpful. The master was a captain with many years at sea in many parts of the world; the author attaches much benefit to discussions with him on the bridge. It is a pleasure to thank all personnel aboard the ship for their assistance.

## Table of Contents


| | page |
|---|---|
| 1. Introduction | 1 |
| 2. The Ship | 2 |
| 2.1 Introduction | 2 |
| 2.2 Ship's Condition | 2 |
| 2.3 Watch-keeping System | 3 |
| 2.4 Staffing and Command Structure | 4 |
| 2.5 Ice Experience | 5 |
| 2.6 Emergency Procedures | 6 |
| 3. Task Data Review | 7 |
| 3.1 Introduction | 7 |
| 3.2 Selection of Incidents | 7 |
| 3.3 Analytical Principles | 8 |
| 3.4 Incident Assessments | 12 |
| 3.5 Incident 1 | 12 |
| 3.6 Incident 2 | 14 |
| 3.7 Incident 3 | 17 |
| 3.8 Other Incidents | 18 |
| 4. Conclusion | 20 |
| Appendix 1 - Summaries of Incidents 1 to 7 | 22 |
| Appendix 2 - Maps and Charts on the Ship | 30 |
| Appendix 3 - Publications and Ship's Documents | 34 |

The author's present address is shown below. Interested parties are asked to forward inquiries to this location.

Polar Sea Research Limited
204, Professional Building
740, 4 Avenue South
Lethbridge, Alberta
T1J 0N8

telephone (403) 329-0373
telex (21) 038-49235

## 1. Introduction

A primary objective of the Transportation Development Centre (TDC) is to improve Canadian capability for all-season navigation in Arctic regions, with the intent of supporting commercial resource development in this area. During the voyage of an ice-capable merchant vessel to/from a port in the eastern Arctic in 1982, the author collected data related to encounters between the ship and hazardous ice, and to the decision-making process on the ship during transits of ice-infested waters. This type of information is highly trip-dependent or route-specific. It represents a compilation of observations for the charter of one ship to/from a particular destination at a particular time of the year. The author used some of these data to conduct a project on Arctic Ship Navigation Tasks for TDC. This report is a ship operations study, undertaken to assist TDC with its continuing work on task analysis and the decision-making process aboard merchant ships in Arctic regions.

This report documents the results of these investigations. General information about the ship, Arctic operations, and procedures on the bridge is found in Section 2. In Section 3, from the data collected on encounters between the ship and hazardous ice, several representative incidents are selected, described, and assessed from the point of view of decisions made and actions taken by ship's personnel during the charter. Section 4 of the report presents some conclusions drawn from the findings at Section 3, plus other comments germane to the project. Three appendices of supplementary information are attached to the text for reference purposes.

Standard nautical terms and abbreviations are used for this report. Ice terms and descriptions conform to the International Ice Terminology of the World Meteorological Organization. The version selected for this report is listed by Markham (1). Distance is measured in metres, or sea miles.

(1) Markham, W.E. 1980. Ice Atlas, Eastern Canadian Seaboard. Atmospheric Environment Service, Environment Canada. Toronto, Ontario. 96 pp.

## 2. The Ship

### 2.1 Introduction

Due to the nature of the project, it is not possible to identify the ship by name, by owner, or by mention of any particulars that are unique to the vessel. However, it is necessary to place the ship in the proper context of Arctic shipping. She was classified by Det norske Veritas (DnV) as Ice Class 1A; the hull, rudder arrangement, propulsion plant, shafting, and propeller meet the requirements of Ice Class 1A* at maximum engine rating. Her Arctic Shipping Pollution Prevention Regulations (ASPPR) classification is Type A. The ship's length over all exceeds 185 m, with breadth extreme about 26.5 m, depth moulded to upper deck about 15.5 m, height of radarmast above keel about 46.5 m, and distance from bridge to bow about 155 m. At the summer seawater (B-freeboard) mark, her draft is greater than 11.0 m, with freeboard about 4.5 m, loaded displacement about 41,500 metric tonnes, light ship displacement about 9,500 metric tonnes, and deadweight displacement about 32,000 metric tonnes. Her trial speed and power were 16 kt at 14,600 Bhp. The ship is a foreign flag vessel, and trades to/from Arctic waters on a regular basis. She was purpose-built for Arctic trade, and is equipped for ice and cold weather operations, with bow thruster plant, ice-breaking bow form, ice management appendages, covered motor lifeboats, and other appointments.

This part of the report describes the ship's "state of preparedness" for charters to/from the Canadian Arctic. The watch-keeping system established for ice-infested waters, the command structure on the bridge, the ice navigation experience of ship's personnel, and procedures for emergencies at sea are also discussed.

### 2.2 Ship's Condition

A principle means of assessing the ship's "state of preparedness" for Arctic charters is a comparison between ASPPR requirements and the actual situation. Special equipment, extra personnel, and unusual circumstances are also part of this assessment. Good indicators of "preparedness" are the inventories of maps and charts, ship's (Arctic) documents and nautical publications, and safety or emergency equipment aboard the vessel. The ship's holdings under the first two categories are shown in Appendices 2 and 3, respectively. The range of material is great for each inventory. In particular, the number of Danish charts and publications suggests that considerable thought was given to planning and preparation by the owner. This Danish material was used extensively for the inbound/outbound transit of Baffin Bay and Davis Strait. In fact, these documents were relied upon almost exclusively, taking precedence over charts and publications from other national agencies. The safety and emergency equipment aboard the ship was wide-ranging, and well-maintained. For example, the two motor lifeboats manufactured by Harding A/S were glass fibre (GRP) covered type with constant internal heating via ship's mains; they were equipped and provisioned for extended cold weather use. The davits were inspected and tested on a regular basis. This type of standard operating procedures was also followed for the smoke detector system, the fire alarm system, and all communications and fire fighting equipment. In the author's opinion, the ship was well-found, or well-appointed, for Arctic trade.

The DnV survey report, described in Appendix 3, was available to the author during the voyage. DnV is one of ten classifacation societies that may issue an Arctic Pollution Prevention Certificate, at the authority of the Canadian Government, to the owner or master of a ship that navigates to/from any Arctic shipping safety control zone(s). The survey report must specify that the ship meets all requirements of ASPPR, without exception or extenuating circumstances. To the author's best knowledge, the ship met or exceeded all statutory requirements for her voyage to/from the Arctic in the fall of 1982. This conclusion was reached after consulting with the master, officers, and other personnel aboard the ship. Clearly, the author could not inspect the hull, machinery, shafting, rudder, or propeller for ASPPR Type A conformance, but was, for example, allowed to view the set of declarations by the master, the builder's specifications, and the owner's procedures for Arctic navigation. Access was also permitted to data on the ship's speed and performance trials, and to other information.

Two pieces of special equipment should be mentioned at this time. A small helicopter landing pad was installled amidships to stbd, the purpose being medical evacuations and other transfers of personnel at sea. Before departure, a VARO Noctron V night vision system was purchased by the owner for use on the bridge. Model 9878 is a portable, hand-held unit (standard configuration: 135 mm f/2.8 lens, battery pack, binocular eyepiece) about the size of a small videotape camera. It is a second generation electronic image intensifier, designed for low level observations by available moonlight, twilight, starlight, or sky glow. Personnel on the bridge used this device at night to identify growlers, ice floes and ice cake ahead. It was a very useful piece of special equipment. In some instances, it was the primary (or only) means of identifying small ice hazards in the way of the ship. The night vision system was also used at times of darkness to confirm radar observations of larger hazards (ships, bergy bits and icebergs), and for route selection in pack ice. In the author's opinion, this device is an essential piece of ship's equipment in Arctic regions.

## 2.3 Watch-keeping System

The watch-keeping system established during the voyage was a standard four hour on, eight hour off routine, with the following exceptions. When the ship was transiting ice-infested waters, the complement of officers and and crew standing the watch was doubled. At all times, two officers were on the bridge, together with two able seamen who stood the sea watch. The double watch began south-southeast of Kap Farvel; on the outbound part of the voyage, it ended south-southwest of this location.

The sea watch identified hazardous objects, and generally, observed the way ahead, then reported their findings to either watch officer. The sea watch was not split, with one seaman on the bridge and the other at the bow (on the foredeck or in the foremast crow's nest), some 150 m distant. If the ship was taken off autopilot for maneuvers in ice, one of the seamen was designated the helmsman. In the event of extended maneuvers, the two seamen relieved one another at the helm on a regular basis. At night or during periods of reduced visibility, at least one officer began an almost constant radar watch. In iceberg- and growler-prone waters, this officer normally stood at the Plan Position Indicator (PPI) display for the 10 cm radar on the stbd side of the bridge; where pack ice predominated, he moved

to the PPI scope for the 3 cm radar on the opposite side of the wheelhouse. The 3 cm radar provided notably better resolution of smaller ice features close to the ship than the higher wavelength unit. It was used extensively at night to plan course changes through pack ice of varying concentrations. The watch officers often discussed the differences between the two PPI displays, sometimes in terms of ice features they could detect ahead with the night vision system, or at twilight, with binoculars. The sea watch would contribute their observations to this discussion.

The officers and crew standing the watch were spelled for mess by individuals from the next watch in rotation. This courtesy is the standard maritime practise. It did not appear to disrupt normal bridge routine, or the ongoing navigation of the ship.

## 2.4 Staffing and Command Structure

In addition to a full complement of officers and crew, extra personnel were on the ship for varying periods of time. The voyage was an important charter for the ship owner. Accordingly, an owner's representative was aboard for part of the trip. Though his presence on the bridge did not appear to materially alter or influence the navigation of the ship, a slight lessening of formality was observed during his absence. A second, senior master was also aboard, equal in rank to the ship's master, except in the sense of ultimate responsibility for the ship and her safety. These two individuals frequently consulted one another on the bridge, and acted with apparently similar status and authority. A third master from an associated shipping company was present as an observer for the entire voyage, but did not participate in the day-to-day operations of the ship. The author was also present for the duration, contributing ice and oceanographic knowledge upon request. Lastly, a senior manager with the owner and a surveyor with the owner's assurrance agency were aboard for brief periods of time. They met the ship at mid-charter to observe the satisfactory progression of the voyage, and to gather on-site data for discussions about an ice premium for insurance on part of the trip. Their presence on the ship did not appear to influence the actions of the two senior masters. Two of the less senior officers appeared to exercise greater care and attention to their duties on watch, compared to the already high standard of responsibility before the senior manager's arrival. In general, the effect of extra personnel on the ship was minor. Though more individuals were on the bridge at any given time than the case with watch officers and crew alone, noticeable upset or disruption of normal bridge routine was not observed. Considerable effort was expended by many observers to remain in the background during the trip. Any influence on the daily operations of the ship was not appropriate under the circumstances. Much significance was attached to the presence of the second, senior master during the voyage. His contribution to the success of the charter was recognized by all personnel aboard the ship.

Command of the ship was structured by the owner, and normal merchant marine considerations. The line of authority was unambiguous and clearly defined. Without exception, the master was called or came to the bridge for all difficult sequences of close maneuvers in all types of ice. The other senior master was often present on the bridge as well. The ship's master, however, was clearly in command, and after discussion of salient points by all concerned, officers deferred to him without objection. In addition to

standing a regular watch, the master was on the bridge from time to time during the day. In those instances where he did not take command from the senior officer of the watch, his presence caused the ship to be navigated in a careful, cautious manner during encounters with hazardous objects ahead. At night, the master's absence from the bridge may have led to less conservative performance. For example, the distance of closest approach to icebergs and growlers appeared to be slightly reduced from what otherwise might have been the case.

The chief officer also stood a regular watch on the bridge. Other important duties included maintenance of the ship's official record, supervision of all on-deck operations, trimming and ballasting the ship to ice draft, loading and discharging cargo, and management of ship's business on a day-to-day basis. He also brought the master up-to-date on a varied assortment of ship's developments and operations. These tasks were usually conducted from the bridge, the deck office, or the master's day office.

Other watch officers were paired by experience, one officer generally possessing more of this than the other. Ice experience appeared to be the major factor here; seafaring experience was important also. In the course of normal watch-keeping at any point during the day or night, the officer with greater experience appeared to make the key decisions. Less significant actions were undertaken interchangeably. Officers from other watches did not interfere with this routine. The master, however, would intervene at his discretion, depending on the developing ice situation ahead.

## 2.5 Ice Experience

The ice navigation experience of the master and officers on the ship varied considerably, from none to more than 25 years. During interviews conducted by the author on the training and experience of these personnel, only two individuals mentioned time at sea in Arctic waters where first year sea ice, multi-year sea ice and glacial ice are often found together. The general absence of experience with these three ice types at one time is a significant point, since it is these ice conditions that are usually encountered by ships that travel to/from ports or harbours in the eastern Canadian Arctic. With one exception, all personnel noted their experience with the winter trade in the Baltic Sea, the Gulf of St. Lawrence, and along the St. Lawrence River. Two officers described their time at sea along the Newfoundland and Labrador coast in winter, where the hazard of first year pack ice with icebergs present from time to time is well-known. One officer mentioned his experience with the winter trade through Russian waters in the Barents, Laptev, and Kara Seas. Though the ship's master had not entered Canadian waters in the Arctic before, absence of route-specific experience was not of great concern to this individual. He commented that his knowledge of, and time at sea in, other ice-prone areas was sufficient to properly navigate his ship through these waters. The second, senior master aboard was well-acquainted with conditions in the eastern Canadian Arctic, and along the west coast of Greenland. All personnel were familiar with ship's requirements during assistance by icebreaker, from their experience in the Baltic Sea and elsewhere, with one exception. This individual was a senior officer with limited ice experience. He was paired with the second, senior master for watch-keeping duties. The reasons for this are self-evident.

## 2.6 Emergency Procedures

Officers, crew, and observers on the ship were familiar with procedures for emergencies at sea. These included responsibilities or actions to take during fires, explosions, severe weather, heavy seas, personnel lost overboard, abandoning ship by lifeboat or liferaft, and other situations. This preparation was accompanied by regular testing of many safety systems, including main engine shut-down, general alarm, fire alarm, portable radio equipment, fire pumps, and automatic closing of water-tight doors between bulkheads. Great attention was paid to response-time and actions taken by personnel during lifeboat drills, fire drills, and supervised use of certain emergency and signalling devices. Improvements were made accordingly. Considerable importance was attached to these and other exercises conducted at sea. This attitude was typical of the general approach to operations in Arctic waters. Competent, professional mariners with proper combinations of training and experience were aboard the ship, contributing greatly to the success of the charter.

## 3. Task Data Review

### 3.1 Introduction

During the ship's voyage to/from an Arctic port in the fall of 1982, more than 55 encounters between the ship and hazards in her path occurred. These encounters varied from single episodes minutes long, to complex sequences of close maneuvers or ongoing actions during multiple encounters that lasted for many hours. Decisions were made during the course of every encounter, in direct proportion to the complexity, and length, of each. In this section, factors that relate to these decisions are discussed. This involves an assessment of representative encounters that took place during the voyage. Analytical procedures entail the following tasks: identification of major decisions or sets of decisions made during each encounter; description of circumstances or background for these decisions; a ranking or prioritizing of elements pertinent to each; and value judgement of important actions taken at the time by the master or officers on the bridge. The selection of encouters for this type of assessment contributes to the relevance, and success, of the analytical procedures. Incident selection, therefore, is also discussed.

Any study of decision-making processes on the bridge of ships must be subject to qualification on choice of approach, methodology, or analytical criteria. The subjective nature of the work described in this report must be recognized. The opinions, interpretations, conclusions, and judgements discussed below are those of the author. The objective was commentary intended to be correct, accurate and most appropriate for the circumstances. The possibility that it is not, in fact, exists. This should not be forgotten by the reader. This section of the report is the author's "best estimate" of what happened during each encounter selected for assessment, what decisions were made, what factors contributed to these decisions, and how they may have been reached.

### 3.2 Selection of Incidents

For the purposes of this study, an "incident" is an encounter between the ship and a hazardous object, or objects, ahead. In this context, the terms "complex incident" and "critical incident" are synonomous. During the ship's voyage, incidents took place involving one or more of glacial ice, first year sea ice, multi-year sea ice, and ships or fishing boats. Icebergs and growlers are forms of glacial ice that pose different problems for operations in Arctic waters, particularly during darkness or periods of reduced visibility. Ice conditions in the eastern Arctic are such that all three ice types may exist concurrently at some locations for much of the navigation year. There are few other northern regions where this is true.

While glacial ice and multi-year sea ice are the only types or forms of hazardous ice usually recognized by the Canadian Coast Guard, first year sea ice presents much the same hazard or risk to most ships from an owner's or operator's point of view. For most practical purposes, in other words, all ice is hazardous aboard an ice-strengthened merchant vessel in Arctic waters. This was the situation on the ship in this project. It is also an influence on the choice of representative incidents for analysis. Another factor is the level of risk posed by the hazard ahead of the ship. An in-

cident normally begins when hazardous objects are positively identified by radar or visual contact. If the hazard is $2^{o}$ or less to port or stbd of the ship's head at the time of indentification, and action is subsequently taken to avoid it, the incident is a "high" threat situation. If no action is taken when the hazard is $2^{o}$ or less to port or stbd of the ship's head, the incident is a "medium" threat situation, since maintaining way did not place the ship in danger. At the time of identification, if the hazard is more than $2^{o}$ to port or stbd of the ship's head, the incident is a "low" threat situation, whether action is taken to avoid it or not. The choice of the $2^{o}$ threshold, and the use of "high", "medium", and "low", are somewhat arbitrary. For example, an iceberg $1^{o}$ to port visible at 15+ miles range is less hazardous to a ship than a growler $1^{o}$ to port at 200 metres distance in twilight, yet both encounters are "high" risk situations, according to this classification. There is clearly far lower potential for collision or damage to the ship in the first case, compared to the second. However, as arbitrary as these thresholds and risk categories appear to be, they provide a convenient, workable means for collecting data on encounters from the bridge, and for classifying these incidents once they take place.

Three complex incidents were selected for detailed study. These offer a maximum range of different hazards encountered over minimum periods of time. All were "high" risk situations initially, two inbound and one outbound, with some overlap of (ice) hazards between each. The choices made, decisions taken, and judgement exercised by the master or watch officers during these complex incidents are representative of the situation for all other incidents. One of the complex incidents chosen for assessment was the most complicated over the longest period of time of any encounter or series of encounters during the voyage. With a good cross-section of ice conditions, hazards, maneuvers, and actions available from three complex incidents, a further four incidents were selected for less detailed study.

This second selection was made after considering the special circumstances of these generally less complicated incidents. Two in this group occurred on the inbound part of the voyage, involving transit (in heavy fog) of regions with often high concentrations of icebergs and different types of sea ice. The remaining incidents took place during the outbound voyage. One involved passage between an iceberg and two ice strips with adequate sea room present to avoid this maneuver, and the other, passage through patches of mixed first year and multi-year ice at night with fog banks in the vicinity.

## 3.3 Analytical Principles

Four principles, or general sets of circumstance, influenced actions during each incident selected for study. In fact, to some degree or another, they were present during every encounter. Proper applications of these principles contribute to the success of incident assessment. Major outcomes or consequences of incidents during the voyage were often determined by one or more of these guidelines. The sets of circumstance this project uses are those relating to hazard detection and perception of risk; the developing ice situation ahead of the ship; the elements of successful decisions and their effect on forward progress; and the master's knowledge of his ship and her performance. It is apparent that some overlap exists between these factors, but this does not affect their use in this report.

Generally speaking, decisions made on the bridge of merchant vessels in Arctic waters should be influenced by the type of ice identified along the track. During this project, however, with one exception, no perceptible distinction was made between first year sea ice and multi-year sea ice by the ship's master, watch officers, or sea watch. These types of Arctic ice were present many times during the voyage, either singly or together. They normally differ on the basis of colour (when bare), freeboard, surface melt pattern, surface texture, and degree of puddling. Salt content and internal strucure also varies from one type of ice to the other. During the voyage, the author observed many external differences sufficient to distinguish first year ice from multi-year ice. For the most part, these differences were obvious; they could be seen from the bridge without difficulty. It was not clear, however, if ship's personnel actually saw the differences, or realized differences were present. The sea watch did not appear to notice; most officers detected the differences, but could not identify the type of ice involved. From past experience, both the ship's master and the second, senior master were familiar with West Ice along the west Greenland coast. This route-specific knowledge, however, could not be used for recognizing different types of sea ice in other Arctic regions.

The sea watch did not comprehend the significance of differences between first year and multi-year ice. Other personnel not did understand the full implications of these differences. An exception is the one instance referred to earlier. This situation involved very heavy multi-year ice in northern Baffin Bay. It was concentrated in strips and belts of small to medium diameter floes (with 3 metres freeboard) and glacial ice fragments. Bergy bits and small tabular icebergs were also present. On this occasion, the ice was unequivocally identified as "multi-year". After this positive identification, the master and officers acknowledged the high risk posed to ship by "multi-year" ice. However, this attitude appeared to reflect the simple, physical dimensions of the situation, or the glacial ice observed. These individuals were not fully aware of the much greater strength, hardness, and density of multi-year ice, or the greater potential for damage it presents. Significant deformation or rupture of the hull of even ice-class ships can occur during low-speed impacts with multi-year ice.

In general, all sea ice was perceived as hazardous, in fact, whether it was hazardous or not. The Canadian Coast Guard's approach was mentioned earlier. In their view, first year sea ice does not present any hazard to shipping. During the voyage, sea ice was sea ice, and it did not appear to matter what type of sea ice was actually ahead of the ship. First year ice was commonly termed "multi-year" when the likelihood of this being true was almost non-existent. For example, it was not recognized that the incidence of multi-year ice in eastern and northeastern Baffin Bay is very low. In the author's opinion, the ship was navigated in eastern Arctic waters as if all sea ice present was the multi-year type.

No distinction perceptible to the author was generally made between sea ice in small floe or cake form, and glacial ice in growler form. Most small pieces of ice were identified as "growlers" by the sea watch, whether this was actually true or not. Furthermore, in some instances, pressure ridge fragments and hummock field remnants were called "growlers" as well. Sea ice is not glacial ice under any circumstances. Characteristics that distinguish growlers from other forms and types of floating ice were poorly

understood by watch-keeping personnel. It was not realized, for example, that growlers are often transparent, but occasionally green or almost black in colour, or that rock, dirt and gravel are sometimes imbedded in the ice. Though many individuals knew that growlers were made from glacial ice, most did not know how to identify them properly. The differences between impacts with growlers and first year ice floes of similar size were not appreciated by the sea watch, but well-known to the masters and officers. Collisions with growlers often cause significant damage to ships; normally, an impact with first year sea ice does not.

These points on identification of ice and perception of risk comprise the first general set of circumstances. Personnel on the bridge identified most sea ice in strip, belt, patch, or tongue form as multi-year ice; most sea ice in small floe or ice cake form was considered to be glacial ice. The correctness of this approach is not at issue. From the point of view of Arctic navigation, it appeared to be an acceptable practise. It caused or precipitated responses to "worst case" scenarios. These situations involve encounters with glacial ice or multi-year sea ice, the most hazardous types of ice in Arctic waters. The conservative strategies that resulted appear to reflect the limited experience of the master and officers on the ship with complex ice conditions in eastern Arctic regions. In particular, this is true for navigation in Lancaster Sound and Barrow Strait.

The developing ice situation ahead is the second set of circumstance. This situation is normally discussed from two point of view, the strategic and the tactical. The former perspective is the long-range situation, typically, from 12 hours to days ahead. The latter perspective, for the purposes of this report, is the situation within working radar range of the ship. Strategic information on ice and meteorological conditions was received by radiofacsimile, radio (key and voice), and telex transmissions. Some data were provided by the organization that chartered the ship. Other reconnaissance was supplied from time to time by masters of vessels in the region ahead of the ship. While strategic information did not influence the actions taken during any given incident, it certainly contributed to route selection and planning on the bridge. This ongoing activity was normal ship's business, which continued to take place during many incidents, and at most other times of the day or night. The tactical picture involves all events and conditions that describe an encounter as it starts and then progresses. This includes pertinent information on the hazard or series of hazards ahead, ice conditions, and other particulars. Tactical components, also influence the availability of options or responses during an incident.

While radar was often used to confirm or identify the developing tactical situation, visual observations were usually relied upon to actually navigate the ship. During close maneuvers in pack ice, or through clusters of growlers or ice floes, visual sources of information were almost totally dominant. Even during periods of reduced visibility, darkness or twilight, visual choices were made to the greatest extent possible. Varied, frequent use of binoculars, searchlights, and the night vision system improved the quality of this visual input. Since icebergs are normally targets observed at much longer range than other hazardous objects, radar returns were often the most important sources of tactical information. In general, there appeared to be greater use of radar data by some officers at all times of the day, compared to the ship's master or second, senior master aboard. This

difference may reflect the greater knowledge and experience of these senior personnel, or the role of other factors. In pack ice, when the master took command for difficult manuevering sequences, tactical decisions appeared to be made on the basis of visual choice alone. While the 3 and 10 cm radars were not often used by the master during these sequences, other officers sometimes conveyed information to him verbally, interpreting radar imagery on either PPI display as it developed.

The third principle involves the "success" or "benefit" of decisions made on the bridge. Since accidents did not take place during the voyage, it is not possible to rate the incidents selected for study, or any other incidents, in terms of failure or mistake. An "accident" implies minor or major structural damage to the ship in Arctic waters. This did not occur during the charter. Some collisions between the ship and sea ice were anticipated by the owner from the beginning. particularly during maneuvers in belts or patches of pack ice. Impacts, in fact, did take place during the voyage, but these do not represent accidents or failures. The ship was an ice-capable vessel, purpose-built to break ice for Arctic trade. If no option existed but to proceed through ice, maneuvers that caused impacts that did not damage the ship must be considered successful maneuvers. Similarly, a "close approach" or "near miss" of hazards ahead of the ship can be partly or completely successful consequences of any maneuvering sequence. The choice depends on the history or "fabric" of the sequence. A near miss, in other words, is not always "almost an accident". Conclusions can be drawn about the "good" or "bad" judgement exercised for most close approaches. The "appropriateness" of maneuvers during an incident, or distance of close approach, can also be addressed. 'It must be emphasized that these conclusions are the author's opinions of what constitutes a prudent or imprudent maneuvers, or sound or poor judgement. This is the most subjective aspect of incident assessment. Significant differences could exist between the author's view that particular actions taken on the bridge were correct or incorrect under the circumstances, and the master's, for example, or that of any other individual there at the time.

The familiarity of the master with his ship is the fourth, and final, principle. Without doubt, the master was intimately familiar with his ship and her performance. This was demonstrated on numerous occasions in Arctic waters, at all times of the day, during all complex incidents with the master in command. It was also shown at loading and discharge, but these operations are beyond the scope of this report. With the skill and expertise that only years of experience at sea provide, the master navigated his ship with great decisiveness and certainty when difficult ice and meteorological conditions demanded this requirement. For example, he implemented speed and course changes in concert with varying ice concentrations during long sequences of closely linked maneuvers hard to port or stbd. These changes anticipated the ship's response to the helm. To pass through narrow gaps or openings between floes without impact, the ship must be turned to this heading well before entry. If a series or network of leads is present, the ship must be positioned for the next opening as she transits the last one. This type of maneuvering requires extensive practical knowledge of a ship's turning circle to port and stbd, rudder response, crash-stop distance, and other characteristics at different speeds, drafts, and sea states. The master was also very aware of what his ship could not accomplish. He retreated from situations that posed significant risk to the ship, cargo, and crew.

## 3.4 Incident Assessments

Assessments of three complex and four less complicated incidents are presented below. Seven tables summarize the events, actions, conditions, and hazards that characterize each incident. This information is described at Appendix 1; it supplements each assessment. Accordingly, the summaries should be consulted for relevant particulars.

The three complex situations were divided into convenient "blocks" of observations or groups of developments. This procedure establishes arbitrary boundaries for decisions made over the intervals. Factors that appeared to influence the major actions taken by ship's personnel are identified on this basis. An attempt has been made to rank these factors in order of importance. The outcomes or consequences of decisions for each part of the incident, or during the incident as a whole, have been evaluated from the point of view of "success". This highly subjective rating of "wrong" decisions reached, compared to partly or completely "right" decisions, is a rough measure of response to hazardous situations. The "good" or "bad" aspects of judgement exercised during maneuvers are parts of this estimate. Where possible, an attempt has been made to list certainty considerations. These criteria, for example, address the failure of ship's equipment, the confidence placed on different sources of tactical ice data, gaps in (or lack of) ice reconnaissance information, and the perceived level of risk.

For the less complex incidents, only those special circumstances that set them apart from "normal" encounters are described. These four situations were selected from evidence of commendable or notably poor judgement in the record. Since the author's reasons for this assignment of "quality" are relatively straightforward, and well-documented by the summary of each incident, it is not necessary to assess these situations at length.

All opinions expressed about decisions, actions, and manuevers during these incidents are the author's, based on interpretations of events and particulars recorded at the time of each situation. This does not guarantee that these interpretations, in fact, are correct, only that they are or appear to be "reasonable" for the incident as it occurred.

## 3.5 Incident 1

This complex incident is summarized at Table 1. As the synopsis indicates, iceberg avoidance maneuvers placed the ship on collision course with a crossing merchant vessel. The incident can be divided into two blocks of events, those from 0630h to 0730h, and those after this time. The course change at 0730h was the first action taken to veer away from the crossing vessel. The major action in part 1 was avoiding the two icebergs, at the same time maintaining a collision course that resulted after course changes began. In part 2, the major goal was maintaining adequate sea room between the ship and crossing vessel, but also, avoiding glacial ice closely adjacent to the ship's track ahead.

In part 1 of the incident, an early decision was reached to proceed between the icebergs identified at 0630h. Some time later, this decision was altered to passage south of both icebergs. The two target radar image resolved to three returns at roughly 0650h, the time of the second course

change. This action was taken when the watch officers realized these icebergs were being set to the south more quickly than expected. This movement was caused by normally south-setting surface currents in northwestern Baffin Bay. Rather than pass between two icebergs randomly moving to the south, the ship was brought to a more southerly course. An EBL (electric bearing line) with the 10 cm radar was started on the third target once its non-random, more rapid southward motion was detected. At this point, a mast light was visually sighted; the indistinct outline of a ship was observed with binoculars. The time was deep twilight at local dawn. Concurrently, the EBL confirmed the presence of a collision course between the third target and the ship at 0702h. The ongoing, southward set of the two icebergs eventually led to passage between these hazards, since the watch officers were not prepared to alter course further south, in the direction of the crossing vessel. Closest approach to the first iceberg took place to stbd at 0710h. The ship's speed and course were held as was up to this time. This maintained the collision course with the other vessel. As the close approach occurred, the ship was brought to 260°. This action positioned the ship for the next close approach. The second iceberg passed to port at 0720h. The greater distance to this hazard compared to the first was caused by the course change. The act of passing the first iceberg produced more, but still limited, sea room to stbd. This was used to slightly increase the range to the second iceberg as approach to it took place.

Radar data was the most important factor for decisions made during part 1 of this incident. Proper interpretation of this information by the watch officers contributed to the developing tactical situation. Ongoing consultation between these officers occurred on the bridge. This exchange influenced actions taken by the senior individual. Sensory input was minor. Visual detection of the mast light and outline of the other vessel lent the sea watch some confidence, or encouragement. The more rapid southerly set of the icebergs was not anticipated at the beginning of the incident. The existence of a ship in the area could not be surmised from initial radar returns. A less complicated incident may have resulted had the first action been a course change to the north after identification of two targets by radar. The encounter may have ended with both icebergs passed on port side, without the complication of a crossing vessel in the area. The author's impression at the time, from comments on the bridge, was that passage north would be off the planned track.

In part 2 of the incident, the major objective was avoiding the iceberg to stbd and growler to port as the other vessel crossed ahead. After the course change at 0710h, a collision course no longer existed, but constant attention was paid to the location of the other vessel as the ship closed the distance to it. The 2.1 mile distance of close approach at 0748h was reasonable under the circumstances. With the crossing vessel safely to the south, the ship was brought to a more northerly course. The officers on watch decided not to pass between the growler and small iceberg. As a rule, passage between hazards in these types of situations was usually not attempted. This maneuver limits the number of options available when new hazards are detected at close range during the passage. After three course changes ending 0757h, both hazards were passed to port, the second of these one minute after the third course change. The incident ended at this time. The last change of course also positioned the ship for entry to Lancaster Sound. The master selected a route on the northern side of the channel.

In general, the consequence of actions taken during this incident was successful avoidance of all hazards encountered. The first decision made about course changes at the beginning of the incident may have contributed to its complexity. It is not clear if poor judgement was exercised in this regard. An option that exists for most series of encounters with single hazards is reducing the speed of the ship. Particularly when these hazards are moving with detectable drift, as they were in this incident, slowing the ship may be the preferred action to take. However, time penalties result, depending upon extent of speed reduction, normally an important consideration from the owner's point of view. This "commerce" factor may have influenced the sequence of events during the incident. Clearly, the risk posed by the crossing vessel would have been less if ship's speed had been reduced at the beginning of this situation, and the course altered to a more northerly heading. The fact that the icebergs were setting to the south more rapidly than estimated shortly after identification by radar increased the complexity of subsequent events. This type of parameter cannot be taken into account before the fact. It is not a mistake to be unaware of drift. Prior knowledge of the vessel that crossed the ship's path would have changed the nature of this incident immensely. The senior officer on watch informed the author of this at the time. According to this officer, the risk of collision with ships at sea was the greatest danger to navigation under any possible set of circumstances. He indicated that the course would have been immediately altered away from the area, had he known of the other ship's crossing path before 0630h. For this incident as it occurred, it is noted that the crossing ship had right of way. Maritime conventions obliged the ship to change course, or otherwise avoid the crossing vessel.

## 3.6 Incident 2

Table 2 summarizes the sequence of events during this lengthy series of encounters. Incident 2 was the most complicated situation observed by the author during the voyage. The master was summoned to the bridge very soon after this incident began, and stood the watch with the other senior master. As the synopsis suggests, incident 2 involved a number of difficult encounters in heavy pack ice off the southeast coast of Devon Island. It can be divided into three blocks of observations, or developments. These bracket the ship's transit of three different ice belts. Part 1 extended from 0802h to approximately 1000h, part 2, from 1000h to 1200h, and part 3, from 1200h to 1450h. The quite different actions taken at different stages of the incident are best addressed by these partitions.

During part 1, initial risks presented by the two icebergs were soon overtaken by the well-compacted ice edge extending across the ship's way westward. The feature was detected by radar some minutes after radar contact with the icebergs. It was sighted visually at 0815h. This ice edge was easily the most formidable barrier to ship's progress encountered to that point of the voyage. The ship turned southwest, and ran parallel to the ice edge in search of passage through it. After five course changes ending at 0833h, the ship was taken off autopilot, placed under manual control, and brought about to enter the ice edge. By 1000h, the ship passed to less congested waters beyond this belt of 3:10 to 4:10 multi-year pack ice. Detectable impacts with small to medium floes in the belt were successfully avoided by skilled maneuvering of the ship at slow to half speed ahead. The master's commands to the helmsman were frequently continuous.

After detection of an ice edge by radar and visual means, the only reasonable choice was to turn and run along it. There were no other options available to the master at the time. Stopping the ship or reversing course did not appear to be practical. Decisions to this point were most influenced by the radar and visual data, with minimal input from other sources. From entering the ice edge onward, the master's experience in sea ice, and familiarity with the ship, were the major factors for actions taken to the end of part 1. These influences were augmented to some extent by radar data on the developing tactical situation, and by ongoing discussions with the second senior master and other officers. In the author's opinion, the master's "eye" or "feeling" for sea room between ice floes, and knowledge of the ship's turning circle and rudder response at varying speeds, contributed more to passage without impacts than any other factors.

Part 2 began with the ship continuing west in the less ice-congested waters. A second ice edge, more compacted than the first, was very soon detected ahead. An open shore lead extending to the west along the coast of Devon Island appeared to exist some distance beyond it. The single most significant decision during incident 2 may have been made at this point. The master decided to cross the ice edge and steam west in open water along the coast. The other option at the time was passage of the less congested zone, with a southwesterly change of course toward an area of reportedly heavy ice. As subsequent events were to indicate, the decision made was sensible at the time, but not later on. After some unavoidable impacts at dead slow to slow speed ahead as the 7:10 to 8:10 ice strip was crossed, the ship entered the shore lead, and steamed at half speed through 0:10 to 1:10 open water. After some 15 minutes of travel, the lead became noticeably less open. Some 10 minutes after that, the lead closed, with 10:10 compact multi-year ice completely blocking the way ahead. The only possible course of action was retreat from the lead. With snow beginning to fall, the ship was turned to the east; a search begun for passage to the south or east by 1200h.

During this part of the incident, damage to the ship from low-speed impacts with first year or multi-year ice did not occur. Some of these collisions could be felt, or sensed, on the bridge. Under the circumstances, since impacts with ice could not be avoided, maneuvers that led to them as the ice strip was crossed were successful actions. The difficulties caused by a closing of the shore lead could have been averted. More comprehensive knowledge of typical ice conditions along the coast of Devon Island would have prevented this situation from developing to the extent it did. The master and officers did not appear to recognize that regional surface circulation tends to sweep heavy multi-year ice into Lancaster Sound from Kane Basin and Smith Sound. Glacial ice or thick sections of landfast ice are sometimes also present. The southerly drift often causes this complex ice to "jam" or encroach along the coast. It was not surprising to the author that the way ahead was blocked by 10:10 concentrations of pack ice. The decision to cross the ice strip was not poor judgement, but rather, perhaps less appropriate than deciding to head south to mid-channel, then west on 74° N. As he did in part 1, the master relied upon his experience and good knowledge of ship's performance for close maneuvers in fairly heavy ice as the ice strip was crossed. His search for openings in the strip prior to entry, and clear "feeling" for sea room between floes during the passage were again the most important considerations. Radar data was not used to

any great degree during this part of the incident. The master was highly occupied with maneuvers and course changes, and visual observations of ice conditions at close range ahead. He did not spend significant amounts of time at either radar console. The other senior master, however, transferred this information to him on a fairly regular basis. This master also observed ice conditions, and during transit of the ice strip, went to the port or stbd wing from the wheelhouse to watch clearance (or impact) between ice and the hull. The ship's master became increasingly concerned about inaccurate ice information as retreat from the lead took place.

This retreat continued at the start of part 3. The master appeared to be worried about entering heavy ice to the south. The ice at this edge of the lead contained much glacial ice, plus multi-year pressure ridge and hummock field pieces. Also, as it developed, further passage to the east along the lead would soon be difficult. Rapid drift of ice from the east-southeast was starting to close the shore lead along its length. After some indecision on the best way to proceed, with the ship stopped and consultations taking place between the two masters, a course of action was decided upon, and the ship brought to slow speed ahead. Some unusual maneuvers began at this time. The ship was turned or "wheeled", first through a 360° circle, then through two 180° arcs. This occurred during selection of an opening, or openings, through the ice edge. The rationale for these actions is not understood by the author; it was not explained to him at the time. Possibly, by swinging the ship through these arcs, the master obtained an overall perspective on ice conditions in the area. Or, he positioned the ship to cross the ice edge without major impacts, by selecting an oblique route through narrow openings. In any event, a number of minor collisions occurred as the ship was turned hard to port, then to stbd, and so forth, as transit began. The pack ice thinned almost immediately, from 7:10 to 8:10 at the edge, to 5:10 to 6:10 in the ice belt beyond it. Many pieces of glacial ice were present, ranging in size from small growlers to small tabular icebergs. This zone of mixed ice appeared less concentrated to the southwest. The ship was turned to this heading, and left the ice for open water by 1450h.

Small impacts with ice floes could not be avoided as the ice edge was crossed. In the ice belt, impacts with glacial ice or multi-year sea ice were not observed (or felt) on the bridge. Decisions about speed and course changes, therefore, appeared to be reasonable under the circumstances. The master successfully maneuvered the ship through ice to open water during this part of the incident. His actions to reverse the inopportune entry to the shore lead were also successful. No change was observed in the factors contributing to decisions made on the bridge from part 2 to part 3, nor was there any change in the ranking of these influences. However, the master was clearly more concerned about the possibility of damage from collisions with glacial ice as exit from the lead took place. The glacial inclusions were more numerous and more hazardous, compared to earlier occurrences.

In general, decisions made by the master and officers appeared to be correct under the circumstances. While close approaches between the ship and many different types of ice took place, these events did not reveal or suggest the presence of poor judgement at the time. None of the observed impacts with ice were avoidable. Since damage to the ship did not appear to result, these collisions involved successful maneuvers. The importance

of this complex incident does not relate so much to the style or manner of decision-making on the bridge as it may to the number, range, and necessity of decisions reached. In the course of more than six hours on the bridge, the master implemented in excess of 155 course changes and 32 major speed changes. These totals do not include minor course and speed adjustments during close maneuvers. Small corrections were made on a continuous basis; it was difficult to record these changes by instance or single event. The author perceived anxiety and apprehension on the bridge, which appeared to increase with time as the incident grew more and more complex. The actions taken to enter the shore lead, and the difficult ice conditions after this point, contributed to the changing psychological environment on the ship. It should be recognized that the master's decision about entering the lead was not incorrect at the time. The subsequent closing of the lead could not be predicted, or taken into account before it happened.

The decision to enter the shore lead, and many other decisions during the incident, were based on the latest ice reconnaissance information received by radio and radiofacsimile broadcast. This information, however, was not accurate, as the situation after the incident began clearly demonstrated. From the ice reports available before the incident started, the master was not expecting multi-year ice north of mid-channel. He selected a northern track through Lancaster Sound, in fact, when the southern route presented almost ice-free conditions. His interpretation of recent ice reports was heavy ice to the south. The master cannot be faulted for his annoyance at this discrepancy between reported ice concentrations and actual ice conditions encountered along the track. During retreat from the shore lead and passage of ice to the south, this situation may have contributed to his cautious, but decisive, command of the ship. The master appeared to be most determined about locating open water as quickly as possible. After this incident ended, at later stages of the voyage, he did not place great confidence in radiofacsimile ice reconnaissance, concluding it could not be relied upon to properly navigate the ship.

### 3.7 Incident 3

This incident is summarized at Table 3. It is not studied to the same extent as incidents 1 and 2. For the circumstances observed, it is not appropriate to divide the incident into different parts. Rather, it is reviewed on the basis of the key decision reached almost as soon as it began. The master acted on suggestions by Coast Guard personnel to remain at or below 74° N on the outbound track to Baffin Bay. Various concentrations of multi-year ice with glacial inclusions had been reported on the northern side of Lancaster Sound. The recommended, more southerly route was based on ship reports, and helicopter reconnaissance flown by the icebreaker's ice observer. After the master's experience with this type of ice during complex incident 2, he did not hesitate about altering course, and brought the ship to a southeasterly heading.

Incident 3 was the second incident during the voyage involving possible collision courses between the ship and other vessels. In an area with as few ships regularly trading on a commercial basis as the eastern Arctic, this situation is unusual. While this observation about the incident is relevant, the more important factor is the information provided by the ice observer. If attention had not been paid to these comments about ice con-

ditions further north, greater complexity would have characterized this incident. Less risk was posed to the ship by the expected, less severe ice concentrations along the southern route.

After correct identification of the hazard detected at 2335h, and the master's receipt of new ice information from the ice observer, the ship began her turn to the southeast by 2340h. Some two hours later, the course was brought to an easterly heading for the passage off the coast of Bylot Island and across northern Baffin Bay. From 2343h to 0440h the next day, more than 68 course changes and a number of major speed changes were made in response to the developing tactical situation ahead. This value was not recorded, nor was the number of minor course and speed adjustments through isolated zones of heavier ice. In general, maneuvers during this incident were less closely spaced and undertaken at relatively greater speed, compared to actions during other complex incidents involving different types of sea ice. One exception is the set of linked maneuvers through a patch of 6:10 to 7:10 pack ice, beginning at roughly 0238h. This part of the incident, for example, shared much with strategies used at incident 2. The notable difference was the presence of darkness. This required somewhat more dependence upon radar for tactical ice information, compared to unassisted visual observations. The night vision vision was used from time to time during this part of the incident.

There is little doubt in the author's mind that past experience began to play an increasingly more important role on the bridge. An ability to better handle the ship in ice at night was apparent among watch officers. In practical terms, these officers appeared to have improved finesse, or "feeling", for anticipating ship's response to the helm during maneuvers around or between small ice floes and ice cake. Except for the night-to-day reversal of importance between radar and visual observations, and the increasing likelihood of only first year ice ahead, the type and ranking of factors that contributed to actions taken on the bridge did not materially change during this incident. No impacts with first year or multi-year ice were detectable on the bridge; all hazards were successfully avoided. The latter success includes the two ships identified at the beginning of the incident, which were given a wide berth with substantial sea room to stbd.

As is transpired, it was very sensible for the master and officers to follow the advice provided by the ice observer on the icebreaker. They were correct not to ignore it. Since even below 74° N significant concentrations of sea ice were found, the "reasonableness" of their actions in this regard is evident. This was a departure from the attitude of some watchkeeping personnel during the inbound part of the voyage. These individuals attached little confidence to most ice reconnaissance data received on the ship, except for reports from other ships in the region.

### 3.8 Other Incidents

Four less complex incidents are summarized at Tables 4 to 7. These situations are briefly described for the extenuating circumstances or special aspects that set each apart from the more "normal" encounters that took place during the voyage. The judgement exercised by watch officers on the bridge at different stages of each incident greatly influenced the choice of situations for this review.

Incidents 4 and 5 occurred within 2.5 hours of each other on the inbound part of the voyage, suggesting that the lesson of the first incident was not followed during the second. In retrospect, incident 5 may be the one encounter of any during the charter where significant damages to the ship came the closest to occurring. If the fog had not thinned some one or two minutes before closest approach after the course change, collision with the ice floe at full speed could have taken place. Response to this hazard was immediate. Close approach, however, was still a distance of only two ship widths from the ice floe. Without evasive action, the probability of an accident or impact would appear to have been relatively high. It is the author's view that full speed was not a prudent choice for passage. This is particularly true for the region where incidents 4 and 5 occurred - an area with glacial ice and sea ice often both present at this time of year. As each synopsis indicates, effective visibility was almost zero in heavy fog during these incidents. Poor judgement was exercised by watch-keeping personnel; some consideration to reducing ship's speed was not perceptible to the author. The greater risk posed to the ship by full speed transit did not appear to be recognized by the officer on watch at the time. The turning circle and rudder response at full speed cannot accommodate major course changes after detection of hazards at close range ahead. Only good fortune may have prevented an impact during incident 5. Heavy fog severely limits options for identification and avoidance of most hazardous objects in Arctic waters. Only radar confirmation of icebergs will likely occur. Accordingly, caution should be exercised during periods of low visibility.

Incident 6 is summarized at Table 6. This incident occurred at night in fog during passage of mixed first year and multi-year ice. Glacial ice was not present. In contrast to actions at incidents 4 and 5, ship's speed was altered for heavy fog. On a number of occasions, the speed was brought to slow or half ahead before entering fog banks, or as the fog set. It was increased at exit, or as the fog lifted. Ongoing awareness of greater risk at times of reduced visibility was evident. A constant radar watch was kept by one of the officers on the bridge; one of the sea watch used the night vision system (by moonlight) to identify ice floes, cake and brash in the varying fog and clear conditions. As the incident progressed, the ship was taken off autopilot, and put at manual helm for better maneuverability in the ice ahead. From the author's perspective, good judgement was exercised during this incident by both officers on watch. Ship's speed at different visibilities appeared to be reasonable under the circumstances. No impacts with sea ice were detectable on the bridge. In general, all actions taken during this incident appeared to be correct. The author concluded that excellent seamanship was demonstrated by ship's personnel at the time.

An interesting set of actions during incident 7 was observed by the author. It is not clear why the ship passed between the ice berg and ice tongues, when sufficient sea room appeared to exist to the north to fully avoid this maneuver. Perhaps, it was a matter of the detour being too large to undertake at this point of the voyage. The course of action decided on did not pose any significant risk to the ship. However, the magnitude of the initial course change was rather high, which may suggest the presence of extenuating factors not known to the author. The watch officer on the bridge at the time was not prepared to discuss this incident at any length. His actions during the encounter were correct, in the sense that no impacts or collisions occurred, but possibly, not the most appropriate to take.

## 4. Conclusion

Decisions made aboard ice-capable ships in Arctic regions are based upon complex combinations of data from many sources. This ship operations study identified, and addressed, some of these influences. Selected sets of circumstances during encounters between a merchant ship and various hazards to navigation in Arctic waters have been analyzed on this basis. The major conclusions the author draws from this work are now discussed.

The ship was well-found and properly appointed for charters to/from the Canadian Arctic. Good preparation for the voyage appeared to improve the quality of decision-making on the bridge, and the extent of competent, knowledgeable opinion aboard the ship. The general condition and arrangements of the vessel appeared to meet or exceed the statutory requirements of ASPPR. Special equipment and extra personnel were relied upon to an important degree. The watch-keeping system was well-organized under the circumstances, with two officers and two able seamen as the sea watch on the bridge at all times in Arctic waters.

Perception of threat was a major influence during the voyage. The great majority of sea ice encountered by the ship was identified as multi-year ice by the master and officers, in fact, whether this ice was actually multi-year or not. The author did not detect any significant difference in the master's perception of risk posed to the ship by first year compared to multi-year ice. It appeared that from the master's point of view, all ice was hazardous or dangerous; decisions were made on this basis. Personnel on the ship did not appear to recognize the differences between first year and multi-year ice along the route. For the most part, these individuals did not appear to fully understand how such differences might affect the ship's integrity or performance at impact. First year and multi-year ice floes were often incorrectly identified as (glacial ice) growlers; evasive action was undertaken accordingly. Most small pieces of ice were "growlers" to the sea watch, regardless of actual ice type. Most personnel realized that collisions with glacial ice would damage the ship, but appeared to be unaware that impacts with first year ice should not cause deformation or rupture of a hull classed to ASPPR Type A requirements.

Perceived risk often appeared as crucial or contributory to what took place during an incident as the true risk actually presented by collisions or difficult maneuvers. On a regular basis, in other words, first year sea ice was avoided as if it was multi-year sea ice, and first year or multi-year floes were avoided as if these were pieces of glacial ice. This circumstance was often complicated by incomplete knowledge of what ice types and conditions could be expected at particular locations. An iceberg or bergy bit was identified and avoided on the basis of what it represented. These features were large, hazardous, and obvious threats to the ship.

In general, of the many factors related to decision-making during the voyage, the most important were ice navigation experience, familiarity with ship's performance and characteristics, communication between watch-keeping personnel on the bridge, and visual information sources on the developing tactical situation ahead. Prior, route-specific knowledge did not appear to contribute to actions taken on the bridge, that is, until the awareness about Arctic conditions began to improve as the voyage progressed. Though

data from two different radars was constantly available at all hours of the day, it was only relied upon to any great extent at night. When encounters with icebergs occurred, an attempt was often made to visually confirm most positive or "hard" radar contacts. The master and officers tended to trust their "eye" for openings or leads between floes during passage of pack ice zones, and their "feeling" for the situation developing ahead of the ship. The latter element included anticipating the ship's response at the helm, a skill required to avoid hazardous objects at close range to the vessel. Except at night when radar data was used extensively, most other sources of ice information appeared to be of secondary importance, compared to visual choices based on past ice experience of senior personnel.

More than 55 incidents, or encounters, occurred between the ship and various hazards in her path during the charter. Three complex and four less complex incidents were selected for assessment. Accidents did not occur during these seven situations, nor did they take place at any other time. Since, on occasion, it is necessary to collide with ice to make way or passage through it, maneuvers that cause impacts are successful if damage to the ship does not result. This was the case during the voyage. From the point of view of Arctic ship operations, most actions taken by the master and officers were correct for the circumstances of each incident as it developed. Instances of decisions interpreted by the author as incorrect or inappropriate were rarely observed. The right decision can be reached by exercising good or reasonable judgement. Sometimes, it can also come about from poor or improper judgement, if good fortune takes precedence or contributes to actions taken by personnel on the bridge. It is difficult to account for decisions reached on the basis of incomplete or inaccurate ice information, since it is not the fault of the master or officers that this situation later proved to be true. Their responsibilities, of course, extend to safe operation of the ship under any circumstances, without regard for "right" or "wrong" ice reconnaissance. However, their level of concern naturally increased when decisions made fairly on the basis of existing information were later shown to be incorrect or inappropriate. This, for example, was the situation during incident 2, when passage along the shore lead was attempted. It is clear that accurate ice reconnaissance would have altered the character of this incident immensely.

In the author's opinion, the ship was operated in a proper, competent and professional manner during the voyage. In general, decisions were made on the basis of assuring safe and undamaged passage of the ship through a number of different concentrations and types of ice. At no time did it appear to the author that choices were made to the obvious detriment of the ship, cargo or crew. No major impacts with any type of ice occurred during the voyage, nor did the ship appear to be damaged to any detectable extent. Given the usual considerations of most commercial ventures, the guiding approach or principle during the charter was conservative navigation of the ship in ice. It was highly successful for the owner and chartering group, in large part due to the careful, cautious, and well-planned operation of the vessel by the master and officers aboard. The owner's progressive attitude concerning well-found ships for Arctic trade, and long tradition as an experienced operator in northern regions, contributed to this situation. The author's study of ship operations and navigation tasks during the 1982 voyage supports this view. There was no discernable conflict between the commercial objective and piloting actions for passing ice-infested waters.

## Appendix 1

## Summaries of Incidents 1 to 7

Table 1

Summary of Incident 1

| | |
|---|---|
| date & time | 3 September 1982, 0630h GMT at start of incident |
| position | 74°25.8'N, 77°58.9'W (satellite navigator, CRT display) |
| ship data | course 263°, speed 16.2kt, 132 rpm on shaft |
| sea & ice | sea state Beaufort Force 2, 0:10 ice concentration |
| sky state | visibility less than 5 miles in twilight at dawn, scattered cloud overhead |
| hazard ID | 2 radar targets bearing 262° and 259° at range 10.8 miles and 12.8 miles, respectively, at start of incident, confirmed visually soon afterwards |
| type & code | complex encounter with icebergs, growler and merchant vessel, with initial hazard less than 2° from ship's head, and action taken to avoid it |
| synopsis | This incident involved iceberg avoidance maneuvers that placed the ship on collision course with a crossing vessel. Existence of this ship wasn't known when course changes began. Initial radar return was incorrectly identified as an iceberg. Target was confirmed as a ship when the mast light was noticed, after an EBL (electric bearing line) indicated rapid, non-random, southward motion of the feature. Due to its red-coloured hull, first visual sighting led the watch officer to terming the ship a "Coast Guard icebreaker", which changed to "freighter" and cargo ship when deck cranes fwd were observed. Identity of ship was confirmed as "Arctic Tide" after radio conversation on VHF channel 16.<br><br>Course was changed to 260° at 0634h and to 255° at 0650h to avoid the two icebergs identified at 0630h. At 0702h, a collision course existed between the ship and other vessel at present speed and heading. Though the other vessel had right of way, ship could not alter course, since it was now committed to avoiding icebergs. Collision course was maintained; distance to other vessel was 8.6 miles at 0705h. Closest approach to first iceberg was ½ mile at 0710h, and to second iceberg, 1 mile at 0720h, to stbd and port, respectively. Ship's approach to second iceberg occurred after course change to 260° at 0710h, which represented the first action taken to veer away from the crossing vessel. Further maneuvers to stbd were restricted by numerous icebergs north of ship's track, and by small iceberg ca. 8 miles distant, bearing 262° at 0728h. Any change of the ship's course to port was complicated by the path of the crossing vessel, and by a large growler (or small bergy bit) 4 miles away, bearing 259° at 0730h. The other ship crossed dead ahead at 0736h, range 3.8 miles. Closest approach to crossing vessel was 2.1 miles at 0748h. The course was altered immediately to avoid the large growler and small iceberg. After course changes to 262° at 0751h, to 266° at 0755h, and to 270° at 0757h, closest approach to large growler was ½ mile at 0745h, and to small iceberg, ¼ mile at 0758h. The course was altered toward iceberg as first part of maneuvering sequence to bring the ship closer to the south coast of Devon Island, following reports of multi-year pack ice laying south at the entrance to Lancaster Sound. |
| outcomes | Officer of the watch chose to leave autopilot on and speed unchanged throughout the incident. All hazards were successfully avoided; no impacts with very small pieces of brash and ice cake in the vicinity of the ship occurred. The close approaches to hazards were optimum distances of separation, given the circumstances of this incident. |

Table 2

Summary of Incident 2

| | |
|---|---|
| date & time | 3 September 1982, 0802h GMT at start of incident |
| position | 74°23.0'N, 79°34.3'W (satellite navigator, CRT display) |
| ship data | course 270°, speed 15.9kt, 132 rpm on shaft |
| sea & ice | sea state Beaufort Force 1, 2:10 ice concentration |
| sky state | visibility 10 miles at dawn, partially cloudy overhead, snow in vicinity |
| hazard ID | 2 radar targets bearing 271° and 273° at range 10.4 miles and 9.1 miles, respectively, at start of incident, simultaneous visual confirmation |
| type & code | complex encounter with icebergs, ice belts and other ice types, with initial hazard less than 2° from ship's head, and action taken to avoid it |
| synopsis | This was the most complex incident that occurred during the voyage. It began with two icebergs ahead of the ship, followed by an encounter with a well-compacted ice edge extending across the western horizon; a search for routes through this edge; transit of an ice belt to less ice-congested water beyond; an approach to an ice edge more compacted than the first; selection of a course to enter a shore lead apparently beyond it; an entry of this lead with the strategy of following it along the coast of Devon Island to Cape Warrender; retreat from the lead when passage was blocked ahead by 10:10 compact pack ice; a search for routes through the ice belt or patch south of the lead; an unusual maneuvering sequence through this patch; and a final encounter with glacial material in it. This series of events terminated with open water ahead approximately 6½ hours after the incident began. Different parts of the incident were complicated, at times, by reduced visibility in fog and snow squalls, and twice, by disruptions related to (false) high temperature alarms in the engine room. The latter were due to low fault threshold settings.<br><br>The icebergs that began the incident were avoided when the ship turned southwest to head along the first ice edge, in search of passage through it. Closest approach to these icebergs was not recorded. After course changes to 250° at 0824h, 240° at 0826h, 235° at 0828h, 232° at 0830h and 230° at 0833h, the ship was taken off autopilot and placed under manual control at 0841h. A lengthy sequence of speed and course changes began at this time. Between 0841h and the end of the incident at 1450h, in excess of 155 course changes and 32 major speed changes were implemented.<br><br>Important or notable events during the incident included transits of the ice belts that began at 0910h, 1114h and 1305h, with average ice concentrations of 3:10 to 4:10, 7:10 to 8:10 and 5:10 to 6:10, respectively. In these belts, the ice was mostly small to medium multi-year floes with some probable first year brash and ice cake. Glacial ice was observed in the second and third ice belts. These inclusions consisted of small sloping icebergs, larger tabular icebergs, and clusters of rock-encrusted growlers. The unusual maneuvering sequence noted above involved turning the ship through one 360° and two 180° arcs in ca. 2 ship lengths at slow to dead slow ahead, during the early transit of ice belt 3. The incident ended at 1450h, with speed at 15.5kt and the autopilot back on at 270°. |
| outcomes | Iceberg and growler collisions did not occur during this incident. A number of unavoidable, low-speed impacts with multi-year ice took place; no damage to the ship was detected. Decisive action by the master was observed on many occasions. |

Table 3

Summary of Incident 3

| | |
|---|---|
| date & time | 7 September 1982, 2335h at start of incident |
| position | 74°08.9'N, 83°49.9'W (satellite navigator, CRT display) |
| ship data | course 135°, speed 13.6 kt, 127 rpm on shaft |
| sea & ice | sea state Beaufort Force 2, 2:10 ice concentration |
| sky state | visibility 15+ miles in daylight, clear sky, some glare on sea surface |
| hazard ID | 1 radar target bearing 137° at range 11.5 miles, at start of incident, plus concurrent visual sighting of unidentified feature at horizon |
| type & code | complex encounter with iceberg, growlers, two ships and ice strips, with initial hazard less than 2° from ship's head, and action taken to avoid it |
| synopsis | This complex incident began with the ship on possible collision course with a radar target mis-identified as an iceberg. Within minutes, the hazard was properly identified through glare and light haze as an icebreaker laying beam to a tanker or bulk carrier. After a radio conversation with the ice observer on the icebreaker, and his suggestion to stay south of 74°N to avoid multi-year ice (with glacial inclusions) in belts or strips north of mid-channel at the entrance to Lancaster Sound, a new series of events was set in motion. This ended some 5 hours later with the transit of an ice belt in Baffin Bay, east-northeast of Bylot Island.<br><br>After identification of the radar contact as two ships, the course was altered 5° to port at 2340h. The ship was then put under manual control for the duration of the incident. From 2343h to 0440h the next day, in excess of 68 course changes were made to avoid impacts or collisions with sea ice, during maneuvers through 1:10 to 2:10 very open pack ice, interspersed with belts or strips of 3:10 to 5:10 (or higher) mixed first year and multi-year ice cake and small floes. Since part of this incident took place at night, it was difficult to accurately estimate concentration and composition, and whether glacial inclusions were present or not. The distance of close approaches could not be properly determined either.<br><br>Major events during the incident included one close approach to a small iceberg (50m to stbd at 0001h), encounters with ice strips (starting at ca. 0007h, 0102h and 0156h), and two sets of very close maneuvers through a 6:10 to 7:10 ice belt (or patch) roughly 10 to 12 miles across. This started at ca. 0238h; the ice extended ahead of the ship to the horizon. Speed was varied as required during these transits of concentrated ice. Data was not recorded between 0324h and 0430h, due to scheduling difficulties. By roughly 0140h, the ship was brought to an easterly course, and approximately 3 hours later, with 0:10 to 1:10 open water ahead, speed was increased to 13.5kt and the ship placed back on autopilot. The incident ended at this time. |
| outcomes | Information provided by the ice observer on the Coast Guard vessel was considered to be reasonably accurate by the master. It clearly expedited navigation of the ship during this incident. One iceberg, all growlers and all ice floes were successfully avoided. No impacts or collisions of any type were detected from the bridge. The two ships encountered at the beginning of the incident were given a wide berth. |

Table 4

Summary of Incident 4

| | |
|---|---|
| date & time | 2 September 1982, 1740h GMT at start of incident |
| position | 74°19.9'N, 65°22.1'W (satellite navigator, CRT display) |
| ship data | course 270°, speed 16.4kt, 132 rpm on shaft |
| sea & ice | sea state Beaufort Force 0, 0:10 ice concentration |
| sky state | visibility zero in fog, daylight conditions, cloud cover unknown |
| hazard ID | 1 radar target bearing 270° at range 10.1 miles at start of incident, no visual confirmation |
| type & code | encounter with iceberg, with hazard less than 2° from ship's head, and action taken to avoid it |
| synopsis | Forecastle deck of ship was poorly visible at start of incident. This deck is ca. 150m fwd of bridge; effective visibility was zero for ice-coloured objects in fog. On much closer approach, the radar contact was identified as a small iceberg. This took place when the ship was beam to the hazard.<br><br>The target was dead ahead of the ship at 1740h. Course was altered to 272° at 1804h, 273° at 1808h and 270° at 1819h. The ship passed the target to stbd at 1818h, range ½ mile, or less. An indistinct outline of the iceberg was detected from the bridge at 1816h. Length at waterline was ca. 30m; surface topography was slope upwards, away from ship. |
| outcomes | Speed and autopilot were left as was during this incident. An iceberg collision was successfully avoided. |

Table 5

Summary of Incident 5

| | |
|---|---|
| date & time | 2 September 1982, 2000h GMT at start of incident |
| position | 74°21.8'N, 67°30.3'W (satellite navigator, CRT display) |
| ship data | course 270°, speed 15.9kt, 131 rpm on shaft |
| sea & ice | sea state Beaufort Force 0, 1:10 ice concentration |
| sky state | visibility zero in fog, daylight conditions, cloud cover unknown |
| hazard ID | 1 visual target bearing 270° at range ½ mile or less at start of incident, no radar confirmation |
| type & code | encounter with small first year ice floe, with hazard less than 2° from ship's head, and action taken to avoid it |
| synopsis | Forecastle deck was obscured by fog at start of incident. Effective visibility was zero at this time. Radar contact with the target never obtained; it was sighted by the sea watch during a momentary thinning of the fog layer the ship was travelling through.<br>After visual identification of the hazard, course was immediately altered 2° to port at 2001h. A small floe with ice cake passed to stbd at 2002h, ca. 50m distant. Ship was returned to 270° at 2003h. The fog began to lift by 2005h; the way ahead remained 0:10 to 1:10 open water conditions, with some icebergs observed at northern horizon. |
| outcomes | Speed and autopilot were left as was during this incident. Collision with the first year ice floe was successfully avoided. |

Table 6

Summary of Incident 6

| | |
|---|---|
| date & time | 7 September 1982, 0609h GMT at start of incident |
| position | 74°58.0'N, 96°48.6'W (satellite navigator, CRT display) |
| ship data | course 118°, speed 13.4 kt, 124 rpm on shaft |
| sea & ice | sea state Beaufort Force 0, 2:10 ice concentration |
| sky state | visibility less than 1 mile at night, moonlight with clear sky overhead |
| hazard ID | small visual targets bearing 118° at ½ mile range at start of incident, some radar clutter on closer approach |
| type & code | encounter with group of small first year or multi-year ice floes, first contact less than 2° from ship's head, with evasive action taken |
| synopsis | This incident involved ice floes dead ahead of ship, soon complicated by periods of greatly reduced visibility in heavy fog. After course changes to 117° at 0611h and 120° at 0615h, the floes passed ca. 25m to stbd at 0613h. Fog bank entered; AP left on, speed reduced to 8kt at entry. Forecastle deck was not visible during transit of this and subsequent patches or banks of fog<br><br>Ship taken off AP at 0625h to improve maneuverability in alternating clear-to-fog conditions during actions taken to avoid floes and brash ahead. By 0735h, airport beacon at Resolute Bay was visible, roughly 15 miles distant. Ship placed back on AP, and speed increased to 13.5kt. From 0625h to 0735h, course was altered 8 times to avoid small hazards ahead of ship. Speed was changed between 5 and 13 kt, in concert with lifting and setting of fog in the vicinity. Both radars at 1.5 or 3.0 mile range were used to detect pack ice features ahead, with visual or NVS confirmation afterwards, or concurrently if possible. At least 4 different fog banks were entered during the course of this incident. |
| outcomes | Impacts with ice floes or brash were not detected from the bridge, at times of either fog or clear conditions. Speed and autopilot were altered as indicated. No collisions with ice appeared to take place. |

Table 7

Summary of Incident 7

| | |
|---|---|
| date & time | 8 September 1982, 2155h GMT at start of incident |
| position | 74°12.6'N, 66°12.5'W (satellite navigator, CRT display) |
| ship data | course 085°, speed 13.9kt, 128 rpm on shaft |
| sea & ice | sea state Beaufort Force 2, 1:10 ice concentration |
| sky state | visibility 15+ miles in daylight, overcast conditions, high level cloud |
| hazard ID | 1 visual target bearing 085° at range 5+ miles at start of incident, radar clutter on closer approach |
| type & code | encounter with two ice strips (or tongues) and one iceberg, with initial hazard less than 2° from ship's head, and action taken to avoid it |
| synopsis | This incident involved two ice strips extending northeast toward the ship, with an iceberg laying north between them. The range of 5+ miles at 2155h applies to the ice strips; the iceberg was visually sighted on the horizon at 2145h.<br><br>At 2155h, the course was altered 40° to port, to detour north of first ice strip. This placed ship on collision course with the iceberg, after further changes to 048° at 2215h and 050° at 2223h. A decision was then made to pass between the iceberg and ice strips, a series of actions involving 12 course changes that ended at 2253h. The ship was then returned to the original course. Close approaches were 300m to the first ice strip at 2238h, 1.5 miles to the iceberg at 2253h, and 200m to the second ice strip at 2253, laying to stbd, port and stbd, respectively. |
| outcomes | Collisions with an iceberg and first year ice in strip or tongue form were successfully avoided. Speed and autopilot were not changed at any point during the incident. |

## Appendix 2

## Maps and Charts on the Ship

## Appendix 2

### Introduction

This appendix lists relevant charts and maps of Arctic and sub-Arctic waters on the bridge during the voyage. The use each sheet was put to is also indicated. If stamped or otherwise available, the "date corrected to" is shown as well. Maps and charts from four national agencies were found aboard the ship. These included the United States Defense Mapping Agency (DMA), Royal Danish Hydrographic Office (RDHO, Det kongelige Sokort-Arkiv), British Admiralty (BA), and Canadian Hydrographic Service (CHS). Documents in the listing are not shown in the order used.

### American Charts

Pilot Chart, North Atlantic Ocean. DMA no. 16, August 1977/September 1977. stock no. PILOT 16707. information only.

Position Plotting Sheet, $56^{\circ}$–$61^{\circ}$ N/S Latitude. DMA chart 931. navigation.

Queen Elizabeth Islands, Southern Part and Adjacent Waters (Arctic Ocean). DMA chart 15023. corrected to 02-09-1978, edition 3. information only.

Aeronautical Chart of Arctic Region. Global Navigation and Planning Chart. DMA no. GNC1, stock no. GNCXX01 (edition 6). information only.

Loran C Plotting Chart, $60^{\circ}$ to $75^{\circ}$N, $46^{\circ}$ to $106^{\circ}$W (M'Clintock Channel to West Coast of Greenland) Eastern Arctic. DMA chart 7804. not used.

### British Charts

Newfoundland to the Faeroes. BA chart 1904. corrected to 1981. plotting.

Strait of Belle Isle to Davis Strait. BA chart 4110. corrected to 1977. modified reproduction of chart INT 110 issued 31-05-1974 by CHS. plotting.

Godthaab to Godhavn, Greenland - West Coast. BA chart 251. corrected to 1977. navigation.

Davis Strait and South East Part of Baffin Bay. BA chart 235. corrected to 1980. used for marking ice edge from ice maps and radio reports.

Storo to Godthaab, Greenland - West Coast. BA chart 247. correct to 1980. information only.

Kap Farvel to Arsuk O, Greenland - West Coast. BA chart 240. corrected to 1980. information only.

Arctic Islands, Davis Strait to Beaufort Sea including Connecting Passages. BA chart 2177. corrected to 1976. reprint of CHS chart 7000. not used.

Iceland to Greenland. BA chart 4112. corrected to 1977. modified reproduction of chart INT 112 issued December 1975 by West German Government. information only.

## Danish Charts

Kap Farvel - Kap Herluf Trolle (58°55'-61°20'N Br.). Gronlands Ostkyst. RDHO no. 2100. corrected to EfS 444/77. information only.

Kap York - Kap Chalon (75°33'-78°00'N Br.). Gronlands Vestkyst. RDHO no. 3200. corrected to EfS 1578/76. not used.

Holms O - Saunders O (74°20'-76°45'N Br.). Gronlands Vestkyst. RDHO no. 3100. corrected to EfS 1578/76. information only.

Proven - Holms O (72°20'-4°45'N Br.). Gronlands Vestkyst. RDHO no. 1700. corrected to EfS 1371/72, current to 1977. plotting.

Hareo - Proven (70°10'-72°35'N Br.). Gronlands Vestkyst. RDHO no. 1600. corrected to EfS 249/76. plotting.

Rifkol - Hareo (67o55'-70o25'N Br.). Gronlands Vestkyst. RDHO no. 1500. corrected to EfS 1146/74, current to 1977. plotting.

Graedefjord - Hamborgerland (63°20'-65°45'N Br.). Gronlands Vestkyst. RDHO no. 1300. corrected to EfS 1356/77. information only.

Hamborgerland - Rifkol (65°35'-68°05'N Br.). Gronlands Vestkyst. RDHO no. 1400. corrected to EfS 1356/77. information only.

Arsuk O - Graedefjord (58°55'-61°20'N Br.). Gronlands Vestkyst. RDHO no. 1200. corrected to EfS 443/77. information only.

Kap Farvel - Arsuk O (58°55'-61°20'N Br.). Gronlands Vestkyst. RDHO no. 1100. corrected to EfS 1854/77. plotting.

## Canadian Charts

Canada, MOT Northern Operations - Shipping Safety Control Zones. Surveys and Mapping Branch, Department of Energy, Mines and Resources. 1970 overprint. information only.

Hudson Strait to Gronland, Loran A/C overprint. CHS chart 7011. corrected to 16-04-1982, edition 16. plotting.

Davis Strait and Baffin Bay (Eastern Arctic). CHS chart 7010. corrected to 02-04-1982, edition 14. information only.

Crozier Strait and Pullen Strait (McDougall Sound). CHS chart 7935. corrected to 09-07-1982, edition 28. plotting.

Jones Sound, Norwegian Bay and Queens Channel (Northwest Territories, Queen Elizabeth Islands). CHS chart 7950. corrected to 02-07-1982. not used.

Lady Ann Strait to Smith Sound (Northwest Territories, Baffin Bay). CHS chart 7302. corrected to 02-04-1982, edition 14. not used.

Arctic Islands, Southern Plotting Sheet. CHS chart S-178. information only.

Cornwallis Island to Stefansson Island (Northwest Territories, Parry Channel). CHS chart 7830. corrected to 02-04-1982, edition 14. plotting.

Lancaster Sound, Eastern Approaches (Northwest Territories, Parry Channel & Baffin Bay). CHS chart 7220. corrected to 02-04-1982, edition 14. navigation and ice edge locations.

Barrow Strait, Western Portion (Northwest Territories, Parry Channel). CHS chart 7829, corrected to 14-08-1981, edition 33. information only.

Scott Inlet to Pond Inlet (Northwest Territories, Baffin Bay). CHS chart 7217. corrected to 16-04-1982, edition 16. not used.

Bylot Island and Adjacent Channels (Baffin Island). CHS chart 7212. corrected to 02-04-1982, edition 14. provisional sheet. not used.

Padloping Island to Clyde Inlet (Baffin Island). CHS chart 7053. corrected to 02-04-1982, edition 14. provisional sheet. not used.

Cape Mercy to Kangeeak Point (Baffin Island). CHS chart 7052. corrected to 02-04-1982, edition 14. provisional sheet. not used.

Cape Crawford to Cornwallis Island (Northwest Territories, Parry Channel). CHS chart 7503. corrected to 26-03-1982, edition 13. plotting.

Resolute Bay (Northwest Territories, Barrow Strait - Cornwallis Island). CHS chart 7533. corrected to 09-07-1982, edition 28. plotting.

Approaches to Crozier and Pullen Straits (McDougall Sound). CHS field sheet FS4483. project 56-7-3, September 1973. natural scale 1:50000. plotting.

## Appendix 3

## Publications and Ship's Documents

## Appendix 3

### Introduction

Publications and ship's documents pertinent to the the navigation of Arctic and sub-Arctic waters are described below. This material was found on the bridge, in the master's day office, or in the telegraphy room. The listing was compiled from all sources available to the author aboard the ship. It represents the maximum amount of information that could be accessed by an observer not representing the ship's ower.

Publications are shown by country, with a separate section for ship's papers. Though each citation is complete in itself, comments are added to some of the entries to fully explain the subject matter.

### United States

Worldwide Marine Weather Broadcasts. NOAA, Department of Commerce. Naval Oceanography Command, Department of the Navy. June 1980. 133 pp. stock no. 311-046/156.

### England

Arctic Pilot. Volume III. Davis Strait and Baffin Bay with the West and North West Coasts of Greenland, the North Coast of Canada including Hudson Bay, and the Arctic Archipelago. NP12, Sixth Edition. Hydrographic Dept. Ministry of Defense. Taunton, England. 1976. supplement no. 4-1981 plus corrections to 27-07-1981 included.

### Denmark

Den gronlandske Lods. I. Del. Vestgronland. Det kongelige Sokort-Arkiv. Kobenhavn, Danmark. 1976. inkl. Tillaeg nr. 8, 1976, til Den gronlandske Lods, Vestgronland. Farvandsdirektoratet, Nautisk afdeling. (this publication is the Denmark Pilot for West Greenland, in Danish, issued by RDHO).

Radartoninger Vestgronland. Det kongelige Sokort-Arkiv. Kobenhavn, Danmark. 1976. (the title translates as "Radarphotographs, West Greenland", issued by RDHO; this book is a series of radar images that have been enlarged and converted to photographs printed as overlays at scale 1:400000; these overlays are intended for reconnaissance purposes with RDHO charts 1100, 1200, 1300, 1400, 1500, 1600 and 2100, comprising sets of 16, 18, 16, 14, 15, 10 and 11 images, respectively; images in each of these series are numbered consecutively from the south; the preface advises that the photographs are to be used in conjunction with the Denmark Pilot for West Greenland, and should not be relied upon for navigating these waters).

### Canada

Ice Atlas, Eastern Canadian Seaboard. Atmospheric Environment Service, Environment Canada. 1981. 96 pp. catalogue no. En56-55/1981E.

Notices to Mariners 1 to 29, Annual Edition. Canadian Coast Guard (Aids and Waterways), Transport Canada. 1982. 218 pp. catalogue no. TP-390.

Ice Navigation in Canadian Waters. Canadian Coast Guard, Transport Canada. 1977, reprinted 1979. 36 pp. catalogue no. T31-3372.

Meteorological Radio Facsimile Broadcasts for Mariners. Second Edition. Atmospheric Environment Service, Environment Canada. 1982. 32 pp.

Sailing Directions, Arctic Canada. Volume II. Third Edition. Canadian Hydrographic Service, Dept. of Fisheries and Environment. 1978. 298 pp.

Sailing Directions, Arctic Canada. Volume III. Third Edition. Canadian Hydrographic Service, Dept. of Fisheries and Oceans. 1981. 310 pp.

Arctic Waters Pollution Prevention Act, Arctic Shipping Pollution Prevention Regulations. P.C. 1972-2443. Canada Gazette, Part II, Vol. 106(20). SOR /72-426, 10 October 1972. p. 1847-1881.

Approaches to Crozier and Pullen Straits (McDougall Sound). Field Sheet FS 4483 and supporting documents. Project 56-7-3. Canadian Hydrographic Service, Dept. of Fisheries and Environment. 1973. 6 pp.

## Ship's Certificate

Arctic Pollution Prevention Certificate, issued according to provisions of the Arctic Waters Pollution Prevention Act by Det norske Veritas, under the authority of the Government of Canada, at Oslo on 12 August 1982, valid to 31 March 1983; the document specifies the owner and name of the ship, the gross tonnage, the call sign, the lightest operating draft forward and aft, the deepest operating draft forward and aft, and the ASPPR "type" category at these drafts.

Det norske Veritas survey report for the ship's Arctic Pollution Prevention Certificate, describing a survey conducted June 1982; this review involved the ship's International Load Line Certificate, Cargo Ship Safety Construction Certificate, navigation equipment, charts and publications, radiotelephone equipment, radar installations, hull and propulsion plant, master's declarations, gyro plant, autopilot, and other equipment or particulars the surveyor deemed of relevance; the master's declarations are those required by the Arctic Waters Pollution Prevention Act, under SOR/72-426, section 20 to 24 and 26 to 29.